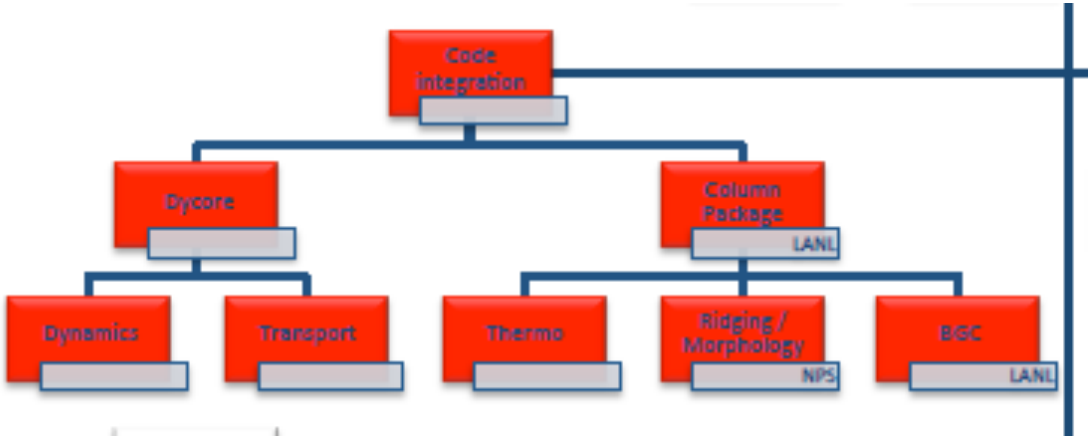

SIS, SIS2 and CICE at GFDL

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Steve Griffies and John Dunne

NOAA/GFDL

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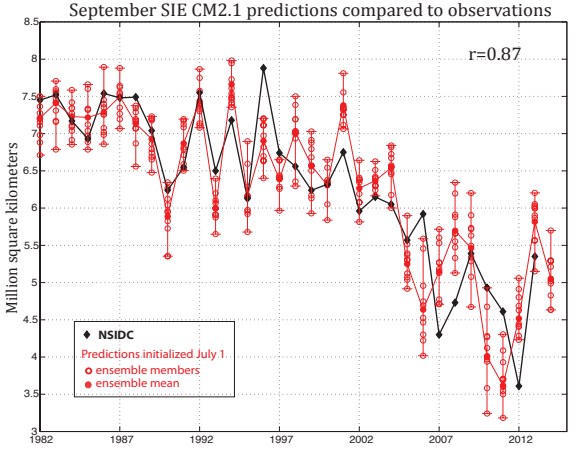
What are SIS and SIS2?

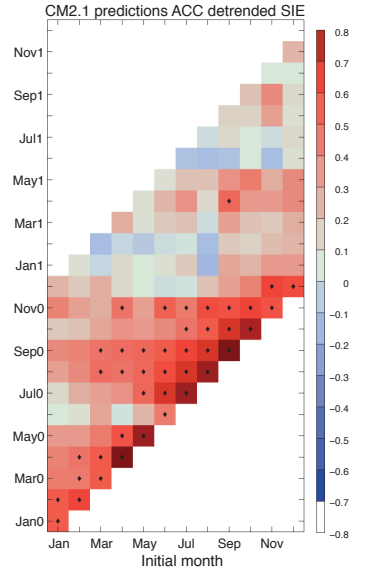
- SIS - 15 year-old sea ice model used by all post-Manabe GFDL climate and ice-ocean models. Predates CICE. Documentation: Winton, M., 2001: FMS Sea Ice Simulator, 11 pp. Released with MOM ocean. Also used by NCEP CFS and elsewhere.

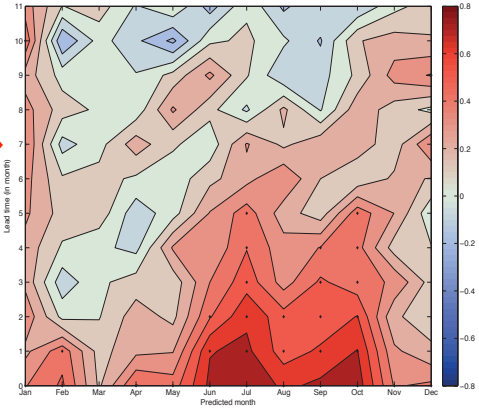
- SIS2 – SIS update for CMIP6 and later. Targeting post-CMIP6 development at forecasting application. Shares code with MOM6 and uses same C-grid. Open source development following MOM6 (github, doxygen)

Goal: Skillful Regional Arctic Ice Forecasts

- Seasonal forecast system makes skillful pan-Arctic sea ice extent forecasts for summer and fall months with leads up to 8 months. It also has some regional skill.
- Can better sea ice processes improve forecast skill?
- Need a full physics sea ice model to answer this





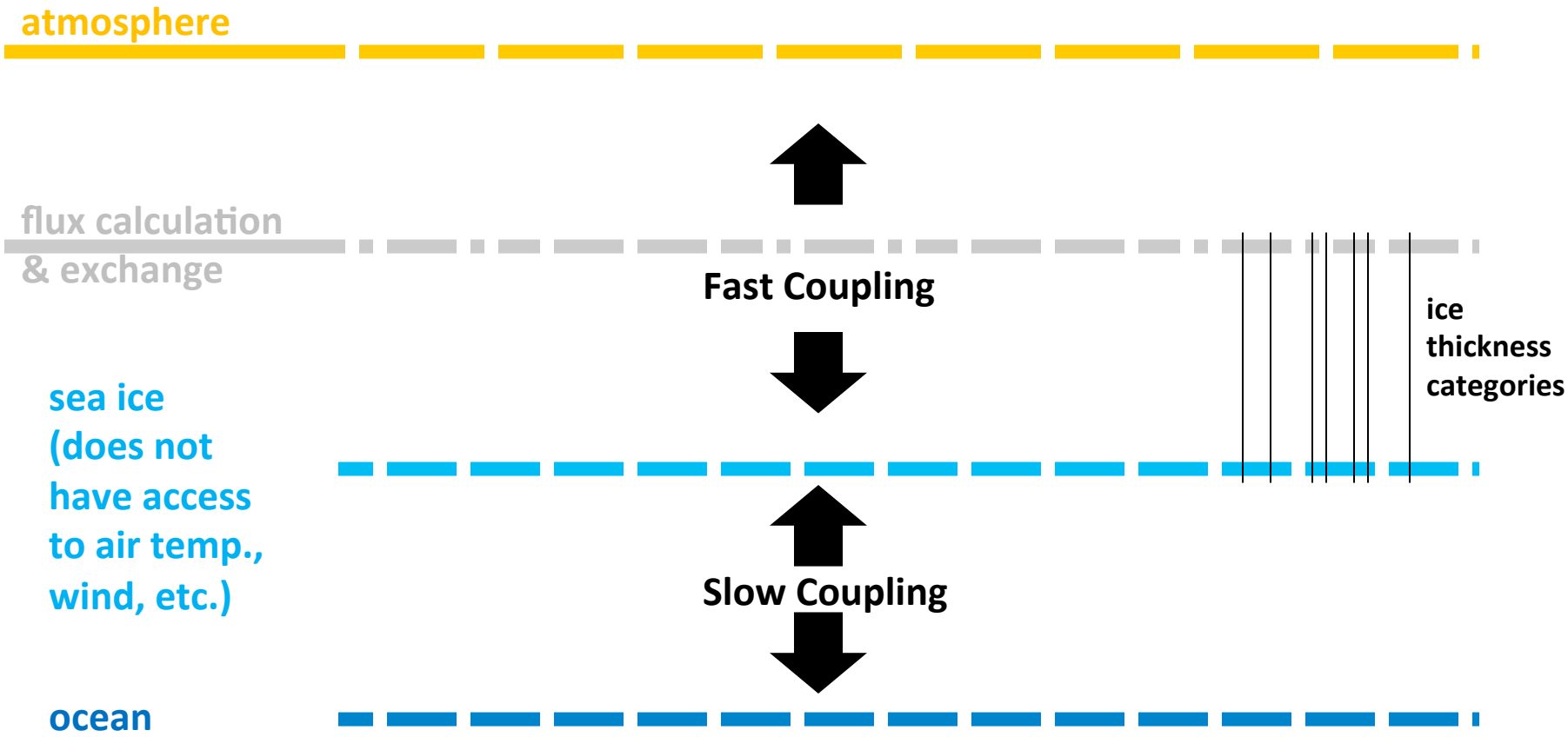


SIS -> SIS2 using CICE components

	SIS	SIS2 (CMIP6)	CICE5
Dynamics	EVP	EVP	EVP
Stencil	B-grid	C-grid	B-grid
Thickness Dist.	5 categories	5 categories	5 categories
Ridging	No	No	Yes
Thermo Layers	2-ice, 1-snow	4-ice, 1-snow	4-ice, 1-snow
Albedo	Parameterized	Delta-Eddington rad.	Delta-Eddington rad.
Melt Pond/ Mushy Layer	No	No	Yes

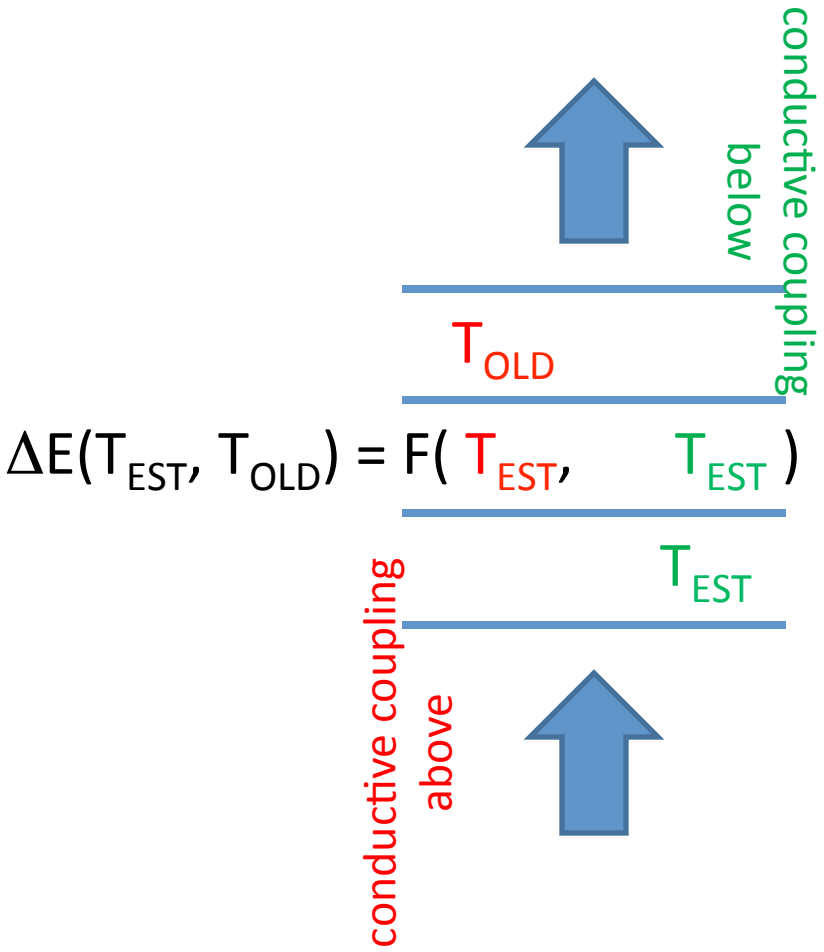
Future SIS2 feature developments

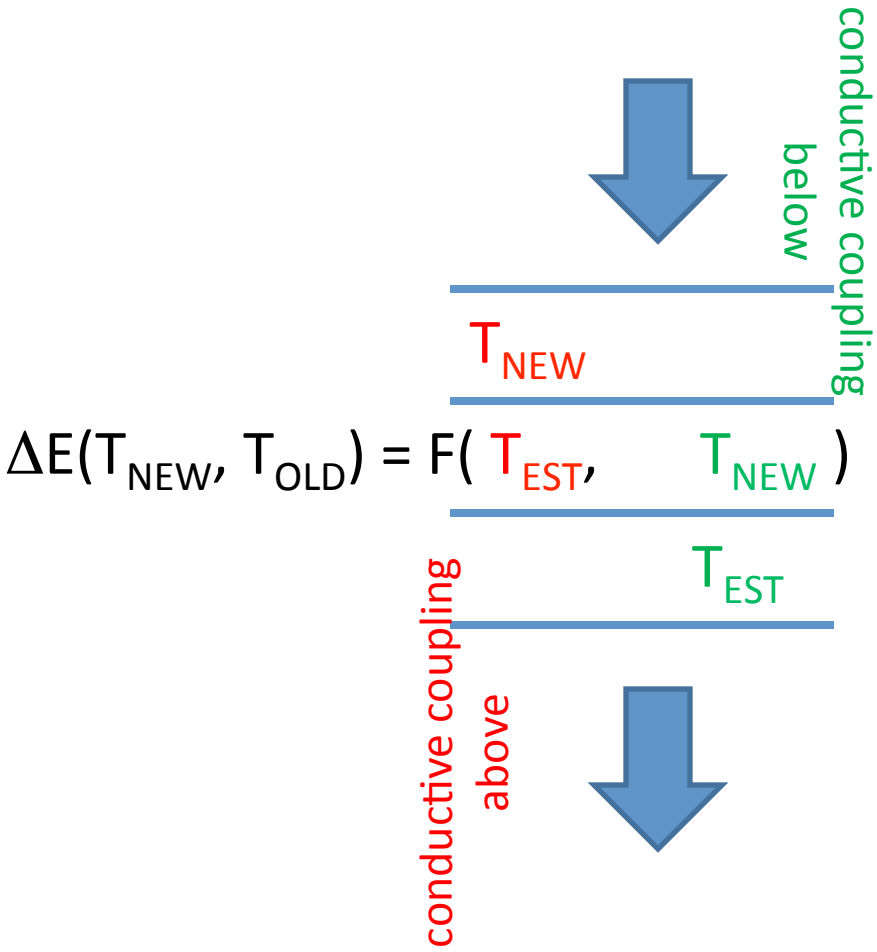
GFDL component coupling (FMS)



* Iterative CICE temperature solver obtains energy conservation by convergence
* Energy conservation without convergence is desirable due to frequent coupling

Temperature solver makes a final energy conserving up-down pass using full nonlinear expression for enthalpy



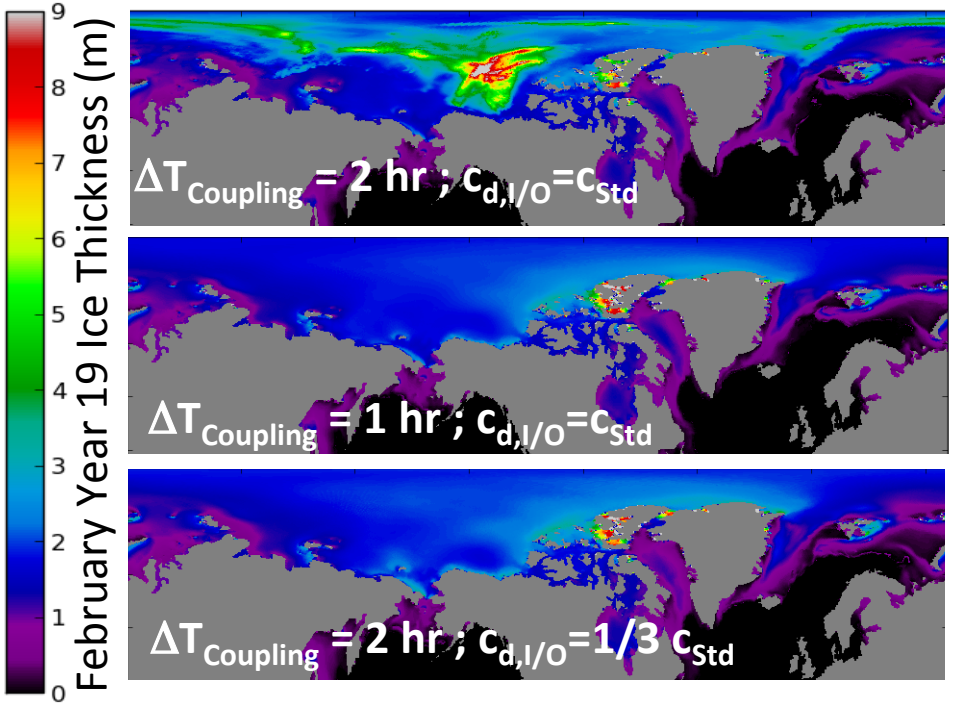


Ice/Ocean Mechanical Coupling Instability

Mixed stress/gravity wave instability causes mid-Arctic thickening of ice.

Instability occurs more readily at higher spatial or ocean vertical resolution.

SIS2 has greater stability than SIS and ocean tracer time step is not restricted to coupling time step in MOM6.

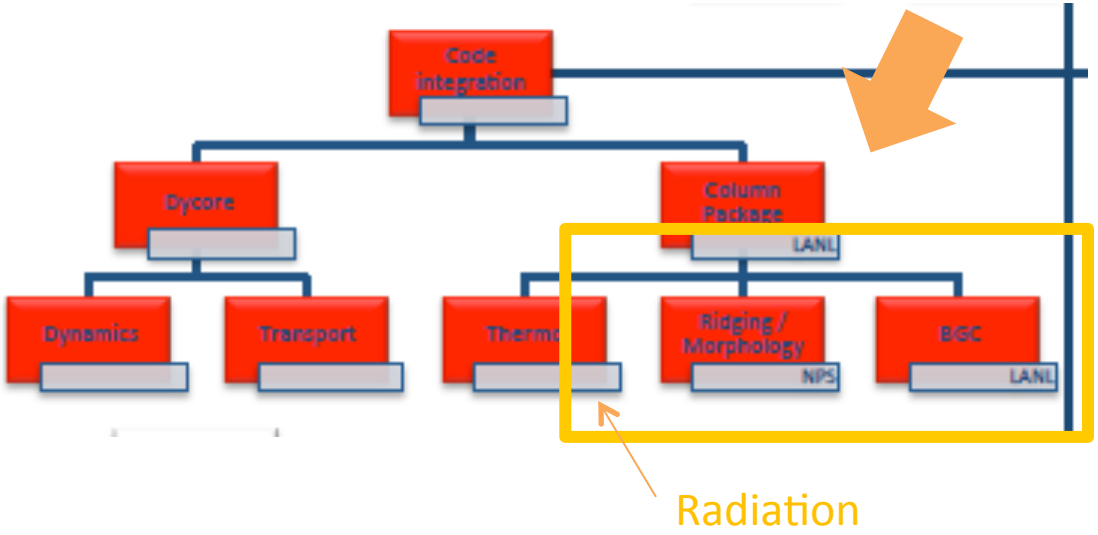


CORE run with ¼°, 75L ALE-based Z* MOM6 (CM4 Ocean Prototype) sequentially coupled with SIS. From R. Hallberg

Ultimate Solution to Coupling Instability:

- Embed sea-ice and iceberg dynamics and slow ice thermodynamics in ocean model:
  - Ice participates in gravity wave dynamics and can displace ocean and ground.
  - Ice-ocean stresses are implicit in both media
  - Melting and freezing does not drive artificial tsunamis.

CICE/SIS2 potential code sharing



SIS2 could use selected CICE column module components:

- Shortwave radiation
- Ridging
- BGC

Coupling CICE components into SIS2

- SIS2 uses shortwave code to generate albedos and transmissivities given ice properties and zenith angle. Ice/snow structure conforms to ice radiation scheme. Atmosphere and ice radiation are not directly coupled. Easy.
- SIS2 uses same Lagrangian thickness category scheme as CICE. Ridging has simple coupling to dynamics (strain rate parameters). Straightforward.
- BGC ice tracer interfaces, coupling to atmosphere (aerosols) and ocean, dependency on prognostic salinity. Not ready yet.

Code sharing mechanism

- *All SIS2 code must be amenable to open source development* (like LINUX OS kernel).
- Open development does not prevent control over “master” code.
- Development MOM6/SIS2 models are built from their open GitHub repositories.
- GFDL, NCAR and LANL currently share open development ocean vertical mixing code (CVMIX) through GitHub.

Getting started SIS2/CICE code sharing

- Column CICE developers place radiation and ridging code into an open GitHub repository
- GFDL incorporates and tests these components in SIS2-based models
- GFDL developers make changes on their own branch but CICE project controls master
- SIS2 adds well-documented, state-of-the-art components and CICE has new customers!